

INTRODUCTION

The 4th edition of the Nuclear Air Cleaning Handbook succeeds three previous editions: ERDA 76-21, *Nuclear Air Cleaning Handbook* (1976); ORNL/NSIC-65, *Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Applications* (1970); and NSIC-13, *Filters, Sorbents, and Air Cleaning Systems as Engineered Safeguards in Nuclear Installations* (1966). It benefits from over 25 years of industry experience since the previous edition was published.

Along with U.S. Nuclear Regulatory Commission documents and consensus standards such as the American Society of Mechanical Engineers (ASME) *Code On Nuclear Air and Gas Treatment* (ASME AG-1), this handbook addresses systems and equipment used in nuclear facilities to capture and control radioactive aerosols and gases. It differs from other documents in that it is intended to be specific for U.S. Department of Energy (DOE) and National Nuclear Security Administration (NNSA) nuclear applications. This handbook is not intended for application to commercial systems other than for general historical information and discussions of basic air cleaning theory. DOE handbooks are nonmandatory documents unless invoked by DOE policy or Order, DOE-approved contractor document, or by contract.

This revision updates the information provided in ERDA 76-21 and incorporates current thinking as provided by manufacturers, subject matter experts from the DOE complex and members of the ASME Committee on Nuclear Air and Gas Treatment (ASME AG-1 Committee). Chapters have been added on History, Fire Protection, and Occupational Safety and Health.

This handbook draws from many special technical areas, each of which requires years of education and practice to master. The authors do not intend to make the reader an “instant expert” in the overall subject or in any of the disciplines of the contributors. For example, reading the chapter on fire protection will not make the reader a fire protection engineer, nor will reading the chapter on gloveboxes make one a glovebox expert. This handbook is intended to provide a very brief overview of the subjects discussed and identify potential issues. Qualified subject matter experts should be contacted for the areas discussed in this handbook.

While this handbook is written for nuclear applications, it is recognized that these systems have shared engineering characteristics that may, with professional discretion exercised by trained engineering and public health professionals, be applicable to nonradiological toxic materials. Such materials include, but are not limited to, asbestos and other particulate carcinogens, beryllium, and biological agents.

We would like to acknowledge the contributions of Humphrey Gilbert, who from the days of the Manhattan Project, was responsible for the initial development of the technology discussed in this handbook. He played a significant role in the development, writing, and technical review of this and previous editions. We wish to express our appreciation to Melvin First, Harvard School of Public Health, who provided a draft that was used in the development of this document; and to Richard C. Crowe, Department Manager for Environment, Safety, and Health (NNSA Service Center), without whose continued support this handbook would not have been possible.

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FOREWORD

TO THIRD EDITION (ERDA 76-21)

This handbook is a revision of ORNL/NSIC-65, *Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application*, which was issued in January 1970. For simplification, the title has been shortened to *Nuclear Air Cleaning Handbook*, and the report has been issued under an ERDA number.

The new edition updates the information of the original volume, corrects some errors that appeared in it, and adds some new material, particularly in the areas of sand filters, deep-bed glass fiber filters, and requirements for plutonium and reprocessing plants. Although A. B. Fuller was unable to contribute directly to this edition, his earlier material on single-filter installation and glove boxes has been largely retained, though rewritten and updated. With this issue, J. E. Kahn of the Union Carbide Corporation Nuclear Division's (UCCND) Engineering staff joins the writing team, contributing particularly in updating the material on glove boxes and writing the sections on sand filters and deep-bed glass fiber filters in Chapter 9. Others who have contributed to this edition include J. C. Little, UCCND Engineering, and a host of reviewers who provided technical evaluation of the draft. Particular thanks are due Dr. M. W. First of the Harvard University School of Public Health, and Mr. Humphrey Gilbert, consultant to the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) and former safety engineer with the U.S. Atomic Energy Commission, for their detailed and thorough review of the complete draft. Others who reviewed the complete draft were J. F. Fish, chairman of ANSI Committee N45-8; J. C. Little, UCCND Engineering; J. C. Dempsey, ERDA Division of Nuclear Fuel Cycle and Production; A. B. Fuller, president of Fuller Engineering; and J. T. Collins of NRC. Thanks are also due to the members of ANSI Committee N45-8 who, perhaps unknowingly, supplied certain data and served as a sounding board for some of the concepts presented in the handbook. We wish to thank the many vendors and ERDA contractors who supplied drawings and photographs used in the book. We also acknowledge the work of Oak Ridge National Laboratory's Technical Publications Department, particularly that of the Composition and Makeup groups, that of R. H. Powell who provided editorial assistance, and especially that of P. J. Patton who edited and coordinated publication of this handbook.

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C. A. Burchsted

Oak Ridge, Tennessee
March 31, 1976

FOREWORD TO SECOND EDITION (ORNL-NSIC-65)

This handbook fills a large gap in the literature concerning air cleaning and filtration, the gap that encompasses design, construction, and testing of very high-efficiency air cleaning systems. The project was originally conceived by Mr. Humphrey Gilbert of the USAEC and was sponsored by the Division of Reactor Development and Technology of the USAEC. In preparing for the project we surveyed air-cleaning systems at atomic energy facilities and industrial installations throughout the United States and Canada. We visited AEC production reactors, commercial power reactors, laboratories, radiochemical plants, reactor fuel manufacturers, clean rooms, equipment manufacturers, and one chemical-biological warfare installation. The purposes of these visits were to review current practices in high efficiency air cleaning and to define the problems in operating, maintaining, and controlling contamination release from very high-efficiency air-cleaning systems from experienced people who were dealing with such problems daily. The handbook reflects a consensus of our findings in these travels, in addition to information gleaned from the available literature.

The handbook is addressed primarily to designers and architect-engineers. We frequently observed a lack of communication and feedback from people with problems in the field to designers. Our intention is to bring to the attention of designers of future systems the kind of problems that an operator faces and what he, the designer, must do to preclude or alleviate them. We have purposely pointed out some poor practices in current design in addition to our recommendations in the hope that such practices will go no further. To give "do's" without "don'ts" may encourage some designers to offer a poor design because he mistakenly believes that "it worked before."

Those who have contributed to the handbook number literally in the hundreds and include those we consulted with and those who have given of their time in reviewing drafts or have supplied specific bits and pieces of information. We take this opportunity to thank the many friends we have made in the course of this project, particularly for their candidness in discussing problems and ways of solving those problems, and for their help in supplying photographs and information. In particular we want to thank Mr. Humphrey Gilbert and I. Craig Roberts of the USAEC for their guidance, W. B. Cottrell of ORNL for his help in getting the book published, T. F. Davis of the USAEC's Division of Technical Information for his assistance in indexing the material, J. H. Waggoner of ORNL for doing the illustrations, and Dr. M. W. First of Harvard University for his meticulous page-by-page review of the draft and suggestions for this final issue.

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Oak Ridge, Tennessee
July 10, 1969

FOREWORD TO FIRST EDITION (ORNL-NSIC-13)

This review presents the latest developments in the trapping of airborne radioactive materials encountered in reactor operations, fuel fabrication and processing plants, and radiochemical plants of all types. The containment of these radioactive aerosols and gases is essential to the safe operation of such installations. Research and development is directed toward increases in containment reliability under adverse conditions, as well as lowered costs and increased efficiencies.

Air cleaning problems and their solutions are related to the physical and chemical properties of the materials to be retained. For example, until recently radioactive iodine was caught on unimpregnated activated charcoal, but recent investigations indicate that the iodine exists in several chemical forms, one of them being methyl iodide, which must be caught on impregnated charcoal.

High-efficiency particulate air (HEPA) filters of fire-resistant fiber glass are now required in the trapping of fine particles in USAEC installations. New HEPA filters for nuclear installations in the United States must show a minimum efficiency of 99.97% for the retention of monodisperse 0.3- μ dioctyl phthalate particles in the standard USAEC Quality Assurance test. A difference of 0.02% is allowed between the rating of new filters by the Quality Assurance test and the rating of filter systems (including single installed filters) by the in-place test. To qualify as high-efficiency, the system or installed filter must have an efficiency of 99.95% in the in-place test.

Radioactive noble gases from high-velocity gas streams must be diluted to permissible concentrations before release to the atmosphere. Noble gases can be removed near the source, but only if treated in small volumes or if low-velocity gas streams are used.

Siting of nuclear power reactors is influenced by the potential hazard of released fission products. Fortunately, a number of transport phenomena, such as agglomeration, absorption, adsorption, deposition, and steam condensation within the containment vessel, serve to reduce the amounts of fission products available for release to the environment. Nevertheless, reactor designers depend on gas cleaning systems as an engineered safeguard to reduce the fission product concentration in the containment system in the event of a reactor accident resulting in fission product release. Clearly, it is important that the effectiveness of various air cleaning systems for removing radioactivity of the types and forms expected in the event of accidents to reactors, nuclear fuel processing plants, or radiochemical plants be demonstrated.

Efforts toward greater reactor safety by the use of engineered safeguards are encouraged by the AEC. However, only limited credit for engineered safeguards is presently allowed in establishing reactor site criteria. Furthermore, the dependability of such systems under accident conditions must be demonstrated beforehand.

Engineered safeguards, in addition to the containment enclosure, are classified into four general types: (1) emergency coolant to prevent melting of the fuel materials, (2) air cleaning systems for removing fission products from the containment enclosure, (3) methods, such as pressure suppression, for reducing the internal pressure, which in turn reduces leakage to the atmosphere, and (4) provision for two or more barriers around the primary system, which will prevent a major leak of fission product activity.

Air cleaning systems are provided to clean the containment atmosphere either during recirculation or by treatment before the air is released to the environment. Several nuclear power companies have installed filter systems in the newer plants, and some credit will be taken in calculating the effects of the maximum accident. A number of the systems have been tested and show >99.99% iodine retention. However, generally only

95% efficiency has been assumed for an installed filter system until detailed behavior of iodine is better established for accident conditions.

The air cleaning system is usually within the containment envelope, where blowers induce air movement through the filter system. Two important considerations are the general reliability of the blowers, filters, filter housings, seals, etc., and the relative vulnerability of the system to damage from particles, missiles, chemical reagents, vapors, etc. This report does not cover engineering design or specifications for filter units or high-efficiency air cleaning systems. An engineering manual, addressed primarily to architects and engineers who are not familiar with the special requirements of such systems, is being prepared for the USAEC by the Oak Ridge National Laboratory and is expected to be available in 1967. The manual will contain design criteria, drawings, and specifications for HEPA filter units and systems in which they are used and will discuss problem areas concerned with the selection and installation of HEPA and activated charcoal filter units.

The methods for trapping radioactive aerosols (including solids and mists) and gases generated in nuclear installations are presented in three parts.

Part I, Fibrous Filters, is concerned with the high-efficiency removal of particles. Here, we review the properties of aerosols, filtration theory, aerosol sampling, analysis of particles, filter media, testing filter efficiency, and the generation of test aerosols for use in testing filters.

Part II, Sorbents, reviews the mechanisms for the sorption of gases and vapors, with particular emphasis on the trapping of fission product iodine and the noble gases.

Part III, Air Cleaning Systems, includes the design of air cleaning systems, in-place testing, filter failures and their prevention, with emphasis on the reduction of fire hazards, and typical engineered safeguard systems applicable to the containment of fission products, including pressure-suppression containment.

At present standard equipment in gas cleaning systems for reactors includes the following: a prefilter unit to remove most of the radioactivity and reduce the fission product decay heat load on later units; next, an HEPA filter to remove very small particles (submicron range); then, a solid adsorber to remove specific gases and vapors. These may be followed by another HEPA filter to protect against any dusting from the solid adsorber. Finally, a high off-gas stack to the atmosphere is required, since nonadsorbable and noncondensable radioactive gases that cannot be removed by the gas cleaning system must be diluted to permissible levels of radioactivity before their release to the environment.